U.S.-SLOVENE SCIENCE & TECHNOLOGY PROGRAM - PROJECT PROPOSAL COVER PAGE

1. Date received: ______________________ (For Executive Agent Use)

2. ID Number: ______________________ (For Executive Agent Use)

3.a Title of Proposed Project: Recovery of Parametric Shape Models in Images

3.b Short Identification Title: ______________________

4. Activity Type: Project x Conference/Workshop ______ Project Development ______ Other ______

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SIGNATURES AND INSTITUTIONAL APPROVALS

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Slovene Principal Investigator

12.b R. Bajcsy Date: 3/28/94
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13.a SIGNATURE Slivnik T. Date: 24-03-1994
Slovene Institutional Director / Fiscal Officer

13.b Berenice Saxon Date: 3/29/94
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14.a NAME: Prof.Dr. Tomaž Slivnik

14.b Berenice N. Saxon
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Research Administration

15.a TITLE: Dean

15.b ______

16. **SUMMARY OF PROPOSED BUDGET**

16.a Exchange rate at time of preparation = 131,8 Tolars/$1 Tolars values are in thousands

	YEAR ONE		YEAR TWO		YEAR THREE		3 YEARS TOTAL	
	TOLARS	DOLLARS	TOLARS	DOLLARS	TOLARS	DOLLARS	TOLARS	DOLLARS
16.b Total Cost	1.318	10.000	1.318	10.000	1.318	10.000	3.954	30.000
16.c Adjustments								

(For Executive Agent Use)

17. YEARS DURATION: Three years

17.a PROPOSED STARTING DATE: October 1994

U.S.-SLOVENE SCIENCE & TECHNOLOGY
PROGRAM-PROJECT PROPOSAL ABSTRACT

ID#:___________

18.a Abstract in Slovene:

Rekonstrukcija parametričnih modelov oblik iz slik

Ena izmed glavnih nalog računalniškega vida je gradnja opisov prizorov sveta, ki omogočajo razpoznavanje in določitev lege predmetov ter ravnanje z njimi. V preteklih letih smo razvili učinkovito paradigmo za rekonstrukcijo geometričnih parametričnih struktur iz slik. Paradigmo smo uspešno preizkusili pri segmentaciji globinskih slik s ploskovnimi modeli in volumskimi modeli, in pri iskanju krivulj na sivih slikah. Cilj predlagane raziskave je razširitev in posplošitev teh rezultatov kot tudi prikaz možnih aplikacij—gradnja CAD modelov iz slikovne informacije in kontrola kvalitete mehanskih elementov, kot dveh najbolj obetavnih možnosti. V tem okviru bomo raziskovali tri medsebojno prepletene probleme: segmentacijo, združevanje globinskih slik in inteligentno zbiranje informacije (načrtovanje naslednjega pogleda).

Med obema predlaganima partnerjema je že dolga zgodovina medsebojnega sodelovanja, ki se je začelo leta 1982, ko je slovenski nosilec projekta začel z doktorskim študijem na University of Pennsylvania. Slovenski udeleženci tega predlaganega projekta so v GRASP laboratoriju prebili skupaj več kot 10 let in pri tem sodelovali pri številnih raziskovalnih projektih. Ta projekt bi omogočil nadaljevanje že dosedaj zelo uspešnega sodelovanja, ki se odraža v številnih skupnih publikacijah. Predlagano sodelovanje bi omogočilo uspešnejše delo na že obstoječih sorodnih projektih v obeh laboratorijih. Projekt bo slovenski strani omogočil uporabo drage raziskovalne opreme, ki je na voljo v GRASP laboratoriju, in ki bi sicer bila za njih nedosegljiva. Na drugi strani, pa bo slovenska stran prispevala k uspehu tekočega raziskovalnega dela v GRASP laboratoriju s svojimi nedavno razvitimi metodami in algoritmi.

18.b Abstract in English:

One of the major goals of computer vision is to recover descriptions of the physical world that enable locating, handling and identifying objects. In the past years we have developed an efficient paradigm for recovering geometric parametric structures in images and obtained encouraging results in segmentation of range images in terms of surface patches and volumetric models as well as in finding curve-models in intensity images. The goal of the research proposed here is to extend and generalize these results as well as to demonstrate potential applications—reverse engineering and automatic inspection of mechanical parts being some of the most promising. In this context we will follow three interrelated avenues: segmentation and merging of range images, and next view planning.

There is already a long history of collaboration between both partners in this project proposal, starting in 1982 when the Slovenian principal investigator started his Ph.D. program at University of Pennsylvania. More than a total of 10 man-years have the Slovenian participants in this proposed project spent in the GRASP Laboratory working on various research projects. This project is intended to enable a continuation of this already very successful collaboration which shows in numerous joint publications (see the bibliography). The proposed collaboration will also amplify the benefits of some of the related existing research projects in both laboratories. The project will enable the Slovenian side to use some of the expensive research equipment available in the GRASP Laboratory which would be otherwise unreachable for them. On the other hand, the Slovenian side hopes to contribute to the success of some of the ungoing research in the GRASP Laboratory with the methods and algorithms that they have recently developed.

19.a Proposed U.S. technical agency for review: **NSF**

Contents

2 Project description and plan of work

This project proposal is an updated and extended proposal that was submitted to the previous U.S.–Yugoslav Joint Board in July 1989. That proposal was reviewed by NSF and put on the priority list of projects for funding in spring of 1991. The decision on actual funding was supposed to be met at the 36th meeting of the U.S.–Yugoslav Joint Board planned for October 1991. Due to disintegration of Yugoslavia the funding of the project was not started.

Research planned in the old project proposal has in the meantime continued and this updated proposal reflects these recent results.

2.1 Present state of knowledge in the field

2.1.1 Background

One of the major goals of computer vision is to recover descriptions of the physical world that enable locating, handling and identifying objects. Since shape information plays a crucial part in these activities, a substantial effort has been devoted to identify proper models for shape representation. Different shape reconstruction methods introduced different shape models, that is models that fit into the particular reconstruction philosophy (bottom-up, top-down or a combination of the two).

Segmentation of images into regions corresponding to single objects or their parts is one of the harder problems in computer vision. Recognition of objects would be easier for a vision system if the system knew which areas in an image correspond to single objects. Segmentation, on the other hand, would also be simpler if the identity of objects in the scene and hence their shape could be found beforehand. It is not obvious which problem should be tackled first. Model-based object recognition systems using feature indexing, which have the advantage of knowing the exact models of objects in the scene, try to identify these objects on the basis of some very specific features first. These local features or combinations of them can be used either to instantiate an object model from a data base or for further aggregation into shape models of larger granularity. We are interested in problems when no apriori known objects are given aside from generic models that encompass a large set of all possible part shapes—our vocabulary for describing the scene. We believe that in such cases the solution for segmentation might well be to do it *simultaneously*—to recover such parts in the images that can be described with a selected part shape vocabulary[4].

The close relation of shape recovery and segmentation is reflected in numerous vision systems where a clear distinction between segmentation, shape recovery and model instantiation is difficult to establish. Most approaches to segmentation in computer vision are based on using local image information, in the form of low level image models such as edges, surface patches and surface normals. Segmentation methods can be divided into boundary and region based methods. Boundary methods try to find significant changes that separate regions in images, while region based methods look for similarity which indicates elements that belong together. When 3-D data is available, surface normals or surface discontinuities (C_0 and C_1) are a commonly used local features. Partitioning then involves thresholding using histogram analysis or clustering in multidimensional space when several features are used simultaneously. Since this features convey very local and noisy information these segmentation methods based on them are unreliable. The problem can be partially alleviated by using coherence measures in a somewhat larger neighborhood. Examples are edge tracking and region growing and using consistency criteria for merging and splitting. Fitting of planar or higher order surface patches in a local neighborhood is a popular method to assure local consistency in range images. Some of these methods derive the initial boundaries of local surface patches from edges and significant changes in surfaces expressed in terms of differential geometry or discontinuities of surface depth and surface normals. The resulting segmentation is often *arbitrary,* even if the similar neighboring surface patches are later merged, which is especially true for nonpolyhedral objects. This is because merging or growing of such small surface regions essentially still relies on local information. If such local segmentation methods are made sensitive enough to detect subtle changes in first or second derivatives in order to find part boundaries, they also become susceptible to noise and details that are not relevant for the final level of representation. Such noise problems can sometimes be handled by following up events in a sequence of images at multiple resolutions.

Much work has been done recently on the problem of reconstructing piecewise-smooth surfaces in one or more dimensions [9,23] which is posed as an optimization problem. In all these approaches the data is weighted uniformly which means that the algorithms do not possess the capabilities to adapt to different conditions in different parts of the image. The global measure, provided by the energy function, is not able to tell which parts of the image are well described in terms of the underlying models and which are not. Also it is difficult to see how these approaches could be extended to subsequent stages of the vision problem without using models with fewer degrees of freedom.

2.1.2 Lessons from human perception

Human visual perception has a remarkable capacity to grasp the overall structure of images. We can easily group the relevant features together and find parts without the need to actually recognize them. The systematic study of this perceptual organization phenomenon was first undertaken by the Gestalt school in psychology. Recently, psychological experiments have shown the particular salience of parts and part configuration functions as a natural bridge connecting perception (appearance) of objects, behavior (activity) towards them and in turn communication about them (naming) [27]. This *special relevance of parts* is due to their level of representation which reflects the natural breaks in the structure of the world. Research in clinical neurology has shown that the human visual system consists of mutually dissociable functions, such as visual acuity, visual shape discrimination, location and color perception [28]. Of special importance to our work is the probable dissociation between visual acuity and shape discrimination on one hand and between shape description and recognition on the other hand. The conjecture hence is that perceptual categorization stage in human vision can aggregate low level features into larger entities or achieve segmentation without semantic knowledge. Investigating models that would play a similar role in computer vision is hence justified.

There were several attempts to define parts as perceived by human vision in mathematical terms. A review is given in [4]. The application of these partitioning rules on real scenes, however, is difficult because of imperfections in low-level shape descriptions. Since part boundaries are defined in terms of differential geometry, the objects in the scene must be described with smooth surfaces so that second partial derivatives can be computed. Normally, edges and other sharp discontinuities must be smoothed out so that differentiation can be done. As an alternative source of information for finding parts contours and occluding contours have been considered. Asada and Brady [1] used a set of images at different scales for segmenting 2-D contours. A 2-D contour is, however, still a locally based shape information and segmentation based solely on it cannot always be consistent. Psychological experiments have also shown that a reasonable amount of noise on occluding contours does not interfere with human capability of recognition [8]. Illusory contours, a well known phenomena in perception, also cannot be explained purely in terms of local image structure.

The problem of using part boundaries to define the shape of parts can be circumvented by directly defining a family of all possible part shapes. Biederman [8] argued that human perception uses a set of primitive building blocks which can describe the wealth of different shapes by combining them like phonemes in a language. Pentland [21] introduced to computer vision superquadric models [5] as a mid-grain shape description language suitable for part-level description. Perceptual grouping is another way to extract the relevant low level image features and filter out the noise in order to reduce the search space when model matching is performed [18,10].

2.1.3 Conclusions

All local segmentation methods, used so far in computer vision, based whether on surfaces or on contours, have problems with arbitrary segmentation. The reason seems to be that an essentially local piece of information cannot decide on the shape of the whole part if the concept of the whole part as such is not defined.

The predictive power of generic models is not used to its full potential when only rules for combining low level models into larger ones are used. If the higher level generic models are well defined, one can attempt to find them in a more direct way. Search can be made more efficient if the objective can be defined in purely mathematical terms. We have already followed this approach and obtained encouraging results in segmentation of range images in terms of surface patches [15] and volumetric models [16] as well as in finding curve-models in intensity images [14]. The goal of the research proposed here is to extend and generalize these results as well as to demonstrate potential applications—reverse engineering and automatic inspection of mechanical parts [19] being some of the most promising. Reverse engineering is researched in the GRASP Laboratory at University of Pennsylvania under the following scenario: one takes a mechanical part, makes a set of range images of it and then tries to find the most compact representation of these measurements, given a prescribed accuracy [12].

2.2 Proposed research

The research proposed in this project will follow three interrelated avenues:

- image segmentation,
- merging of range images,
- next view planning.

2.2.1 Range Image Segmentation

Recent attempts to formalize the problem of image segmentation as a problem of finding a minimum description length encoding of an image in terms of primitives [13,22] led to our development of quite general and successful algorithms that can segment range images in terms of surface patches [15] or volumetric models (preliminary results in [16]) – see Figure 1. In contrast to other approaches in modeling range images with parametric models [11,22] *no presegmentation* is required for our methods.

In our experiments we used biquadratic surfaces and superquadric models [21,25] as surface and volumetric models, respectively and tried to find a minimum description length encoding of a range image in terms of these. Informally, the volumetric models produced by segmentation process represent a decomposition of the object into its parts. Although the results of segmentation look good (Fig. 1), the surface description in terms of biquadratic surfaces shows its inability to describe the surface of a sphere as a single surface patch that would model the whole surface of the sphere (note the gap between regions 1 and 2 in Figure 1). On the other hand, the patch No. 3 clearly corresponds to a single part, while this is not the case for the description in terms of volumetric models. To circumvent the limitations of a particular model type, we will investigate how to combine surface and volumetric models to produce a minimal length description of a range image in terms of both kinds of models.

Recovered parameters of superquadric models from single viewpoint range image are not very reliable description of data [29]. But although, the recovered parameters are not reliable, the decomposition of object into parts is reliable since it is based on the object structure. Additional constraints, such as minimal volume can be used during the iterative minimization of objective function during the

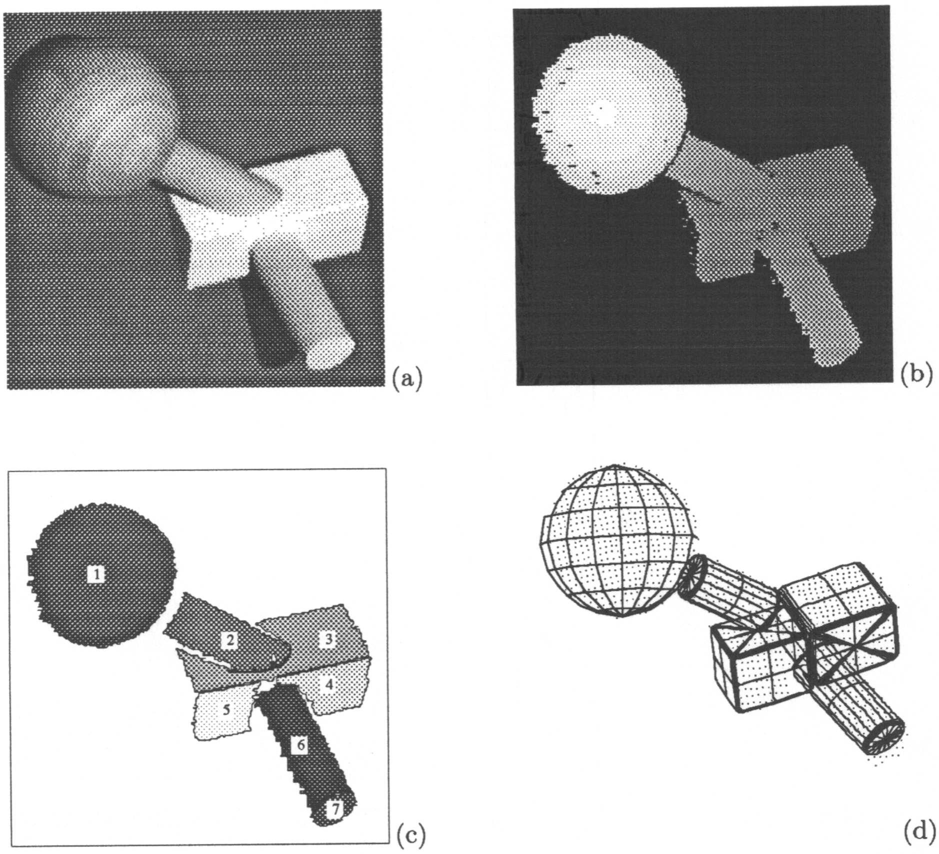

Figure 1: a) Intensity image of the object b) Range image of the object c) Segmentation using surface models d) Segmentation using volumetric models.

recovery of superquadrics to avoid shallow minimum as described in [25,29]. This assumption leads to "visually" acceptable results of model recovery and segmentation of range image.

2.2.2 Merging Range Images

Range image acquisition by 3-D imaging sensors inherently produces only partial 3-D description from a single viewpoint. This description represents a distance between an image plane and points on the object surface in such a way that for each point in the plane there is at most one corresponding point on the object surface. Because of this restriction such description is often referred to as 2.5-D data. We will use the term *range image* to refer to this 2.5-D data and *3-D description* to refer to a set of 3-D points from the object surface. It is quite obvious that each range image is also a 3-D description but the reverse is generally not true.

Evidently, the main reason for partial description is self-occlusion. Besides, geometry of sensor setup might further reduce the space where 3-D data can be deduced (see [20] for example of such sensor setup). In order to produce a complete 3-D description, that is a set of densely sampled 3-D points from the object surface, we have to merge the range images obtained from several viewpoints. The later implies either object manipulation or change of sensor position to achieve a relative change of position and orientation of the object with respect to the sensor. To merge data from different viewpoints into a single coordinate frame, we have to find a rigid transformation between the coordinate frames of range images. We can seldom rely only on a calibrated sensor setup, so even if we have an estimate of a rigid transformation we should not merge the data blindly but still perform a data driven process of range image registration by using local shape matching. A rough estimate of transformation obtained during the object manipulation or sensor repositioning can be used as initial approximation for iterative registration algorithms like the one described in [6].

Of course complete 3-D description of object in terms of surface points is not a suitable representation for computer vision systems. Further data reduction has to be achieved by partitioning the points into separate parts in the process of segmentation. We plan to use superquadrics as parametric volumetric primitives used in segmentation, because of their apparent correspondence to intuitive notion of parts. Besides, they can model quite a rich set of shapes with a relatively small number of parameters [5].

A stable description of objects in terms of surface primitives allows us to develop a novel method of constructing complete geometrical models from range data, that does not require calibrated positioning of sensor setup or calibrated manipulation of the objects to obtain a complete 3-D description. Instead we relay on the object part structure to sufficiently constrain the matching and registration of range images from different viewpoints. The method we intend to develop will be based on integration of existing methods for range image segmentation [15,16] and registration [6]. A direct application of this method is an interactive iterative construction of CAD models, where an operator manually places the object in front of a range scanner in different orientations to incorporate additional data into a current 3-D description of the object. Visualisation of current 3-D description helps the operator to decide about appropriate object orientation for the next range image acquisition.

A current partial 3-D description consists of a set of 3-D data points obtained so far and its representation as a set of volumetric models (superquadrics [25]). Note that the parts of the surfaces of volumetric models that correspond to no data points are just a hypothesis. Each superquadric model also encodes the information about the parameter space of ω and η that has been covered by data points. So a complete 3-D description of a part corresponding to a superquadric covers the whole parameter space of ω and η.

Since we require a data driven image registration procedure, the data obtained from the next viewpoint will have to include the regions of points from the volumetric models that have been reliably recovered from data points and are not just hypothesized in the current description. Thus to obtain a reliable estimate of the rigid transformation we wish that data set obtained from the next viewpoint would be a subset of the points incorporated into a current description. Of course such data would only produce a reliable estimate of transformation but add nothing to build a complete 3-D description. On the other hand one might want to maximize the information from the next view trying to reduce the number of necessary viewpoints to form a complete description [20]. But that might lead to a very unreliable estimate of rigid transformation. Obviously, a trade off between the contradictory requirements must be found for this local shape matching to work in practice.

We will use the part description of the range image produced during the segmentation to find the correspondence between the parts in range image and current 3-D description accounting for possibly missing or unrecovered parts. The initial estimate of rigid transformation is calculated from the transformations of each separate part.

The obtained transformation will then be used as an initial estimate for the modified iterative closest point algorithm that accounts for uncertainty of volumetric models in current 3-D description in the areas with no data points. The distance between the closest point on the superquadric and the data point is weighted according to the uncertainty of the point on the superquadric. That is if the closest point on the superquadric is just a hypothesized point of the current description, the actual distance between the points is weighted less in the error metric.

The visualization of experimental results and computational processes will be used not only to explore and develop our paradigms but also to communicate them to broader scientific community through hypermedia research reports available through our WWW server. We also think that this will significantly increase the reuse of our software tools.

2.3 Plan of work

2.3.1 First year

Existing prototypes of our software packages for image segmentation in terms of parametric models [15, 16] will be used to design and implement an object oriented tool for image segmentation. Novel and improved parametric models, selection and recovery strategies for range images will be tested much easier and faster within this new software environment. Experimental data will be provided by the GRASP Laboratory. The development work on the visualization software tools will start in parallel with the software development work for image segmentation. We expect to finish the segmentation and visualization tools by the end of the first year.

2.3.2 Second year

A range scanner software simulator will be built during the second year, to facilitate fast experimentation in the domain of integrating range images from different viewpoints into a single coordinate frame to obtain a complete 3-D description of objects. We will adapt the existing methods for rigid transform estimation to our description of images in terms of surface and volumetric shape primitives. We will investigate the problem of transforming the obtained shape primitives into standard CAD models.

During the second year we will also try to find suitable parametric models in the domains of motion and stereo for our recover-and-select segmentation paradigm. The following extension will be to try to use the paradigm within a multiresolution representation of images, by using models of different granularities. The main scientific goal will be to experimentally demonstrate that the paradigm is general and not domain dependent.

2.3.3 Third year

We will try to find a next view planning strategy suitable for our parametric models used in range image descriptions. The experiments will be done within the range scanner software simulator and the software package for integration of range images from different viewpoints. Final validation of the proposed schema will be done with real range images.

The tools developed in the first and second year will allow us to search for efficient control strategies needed to perform visually guided tasks under constrained computational resources. The results will be directly applicable in computer vision systems based on active vision paradigm.

2.4 Technical approach, methodologies, and procedures

The validation of our proposed paradigms will be done through experiments with synthetic and real images. In order to do that, we will design and code the necessary software tools for:

- recovery and select segmentation paradigm with emphasis on the visualization of data and algorithms,
- generation of synthetic range images within a standard CAD package,
- merging range images from different viewpoints,
- producing standard CAD models from recovered shape models (reverse engineering).

Due to substantial complexity of the software we will re-engineer some of our existing software to comply with the object oriented programming paradigm. The software will be written in C++ under Unix operating system, with intention to be scalable and portable, so that it can run also under MS DOS or MS Windows. The final goal of this software engineering part of the project is to produce a well designed software package for segmentation that can serve as a component in a larger computer vision system or as a stand alone software tool to experiment with different parametric models, recovery strategies, selection strategies.

2.5 Facilities and instrumentation

2.5.1 Computer Vision Laboratory at University of Ljubljana

The computer facilities of the Computer Vision Laboratory consists of a HP Apollo 715/50 Unix workstation and three X Windows terminals interconnected through Ethernet and three Apple Macintosh interconnected by AppleTalk network. The two networks are bridged and the workstation is connected to the Internet. A full set of Internet services is available, ranging from electronic mail to local WWW servers. The image acquisition facilities consist of a Pulnix CCD black and white camera and 8-bit frame grabber. Currently, we do not have access to a range scanner in Slovenia and we will use the range image taking facilities in the GRASP Laboratory at the UPenn. Later during the project, for implementation of the view planing strategy we will use also the possibilities to manipulate the objects or move the imaging devices with robot manipulators which are available in the GRASP Laboratory.

Most of the funds for this project proposal are hence intended for short or prolonged exchange visits in collaborating laboratories. Beside supplies and publication costs (conference registrations) we plan to buy from the budget of this proposal only additional hard disk storage devices for the existing work station since we already experience serious shortage of storage space for images.

Equipment to buy:

- hard disk drives, (cost estimate $2700), to support the software development and communication of our research results (WWW server).

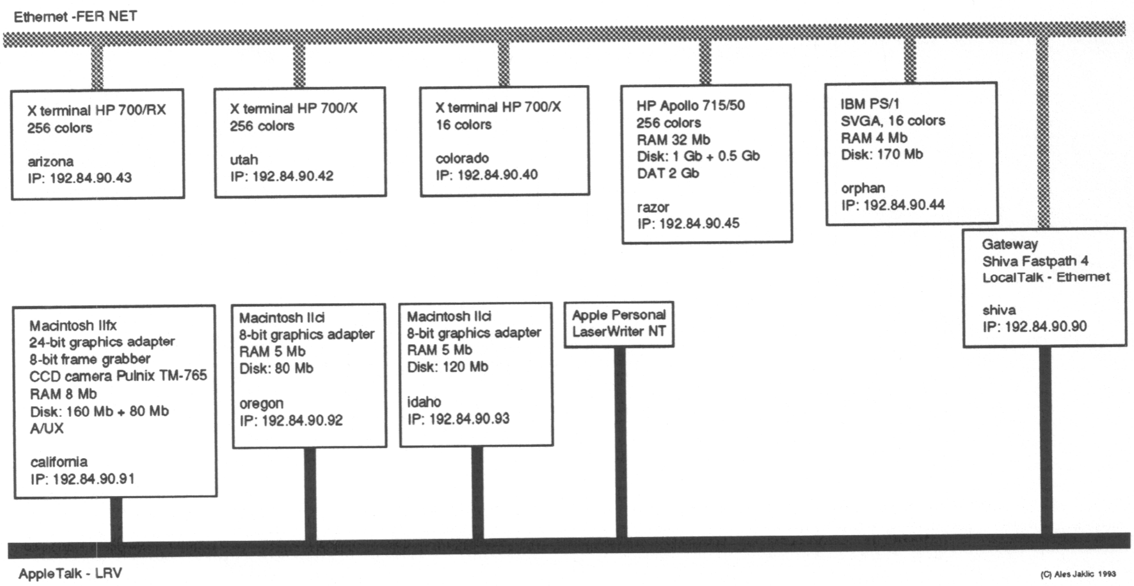

Figure 2: Computer network of the Computer Vision Laboratory, Faculty of EE and CS, University of Ljubljana

2.5.2 GRASP Laboratory at University of Pennsylvania

Equipment in GRASP Laboratory is depicted in Figure 3 on page 8.

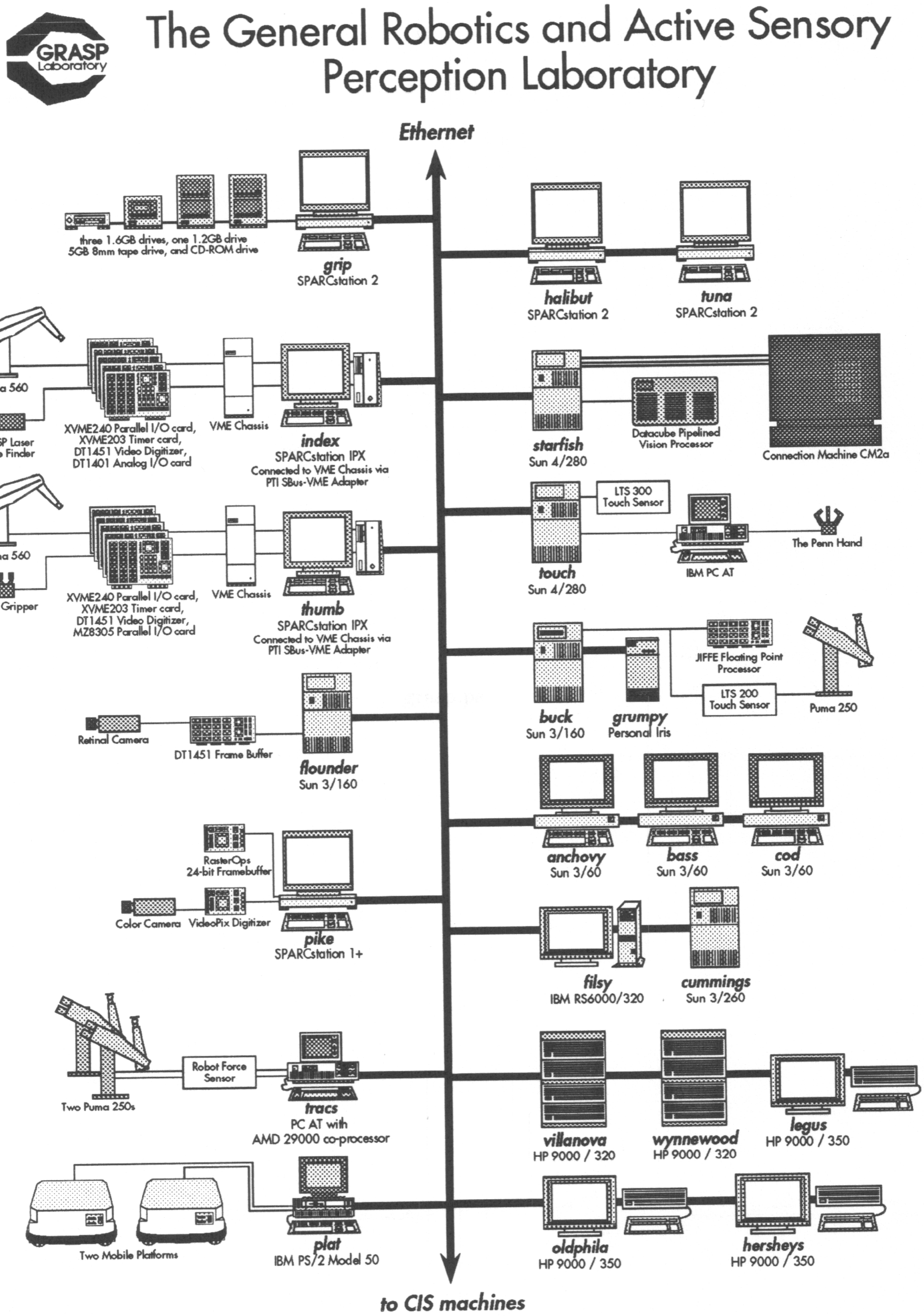

Figure 3: Computer network of the GRASP Laboratory, University of Pennsylvania

2.6 Participants

Computer Vision Laboratory at University of Ljubljana

- Franc Solina, Ph.D., Principal investigator,
- Aleš Leonardis, Ph.D.
- Aleš Jaklič, M.S., graduate student,
- Jasna Maver, M.S., graduate student

GRASP Laboratory at University of Pennsylvania

- Ruzena Bajcsy, Ph.D., professor, head of GRASP Laboratory.

2.7 Previous cooperation

All participants from Computer Vision Laboratory at University of Ljubljana have spent some time in the GRASP Laboratory; Franc Solina (1982–88), who obtained there his Ph.D. degree in computer science, Aleš Leonardis (1988-1991), Jasna Maver (1989–1991), Aleš Jaklič (1990). During our stay at UPenn we participated in ongoing research projects in the GRASP Laboratory which were supported by a number of U.S. governement sources and private industry.

Ruzena Bajcsy from University of Pennsylvania has also visited University of Ljubljana several times, giving lectures and taking part in Ph.D. committees. This project is intended to enable a continuation of this already very successful collaboration which resulted in several joint publications. Some of the more important joint publications are: [3,15,2,4,24,25,20,17].

All previous collaboration was made possible by individual stipends (IREX, Fulbright, University of Pennsylvania).

2.8 Expertise of respective Slovene and U.S. investigators

Previous collaboration amply testifies that the research interests of both parties are well matched.

2.9 Benefits of cooperation

The proposed project will enable a continuous and uninterrupted collaboration between the two laboratories which has already produced results noted in the international computer vision community.

The proposed collaboration will also amplify the benefits of some of the related existing research projects in both laboratories. In the Computer vision laboratory at University of Ljubljana two basic research projects *Recovery of Parametric Models* and *Adaptive Modeling of Environment for Purposive Computer Vision*, both funded by the Slovenian Ministry of Research and Technology, are underway. In the GRASP Laboratory at University of Pennsylvania an ARPA funded project on reverse engineering has started [12].

The project will enable the Slovenian side to use some of the expensive research equipment (Laser range finder, robot manipulators, mobile platforms, Connection machine) available in the GRASP Laboratory (see Fig. 3) which would be otherwise unreachable for them. On the other hand, the Slovenian side hopes to contribute to the success of some of the ungoing research in the GRASP Laboratory with the methods and algorithms that they have recently developed (see the Supporting Correspondence).

3 Bibliography

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[17] A. Leonardis, A. Gupta, and R. Bajcsy. Segmentation of range images as the search for geometric parametric models. *International Journal of Computer Vision*, 1993, To appear.

[18] D. G. Lowe and T. O. Binford, *Perceptual organization and visual recognition,* Boston: Kluwer, 1985

[19] A. D. Marshall, R. R. Martin, and D. Hutber. Automatic inspection of mechanical parts using geometric models and laser range finder data. *Image and Vision Computing*, 9(6):385–405, Dec 1991.

[20] J. Maver and R. Bajcsy. Occlusions as a guide for planning the next view. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 15(5):417–433, May 1993.

[21] A. P. Pentland, "Perceptual organization and the representation of natural form." *Artificial Intelligence,* vol. 28, no. 3, pp. 293-331, 1986

[22] A. P. Pentland, "Automatic extraction of deformable part models," *International Journal of Computer Vision,* **4**, pp. 107–126, 1990

[23] T. Poggio, "Computational vision and regularization theory," *Nature,* vol. 317, 1985

[24] F. Solina and R. Bajcsy: "Recovery of Mail Piece Shape from Range Images Using 3-D Deformable Models," *International Journal of Research & Engineering, Postal Applications,* Inaugural Issue, pp. 125-131, 1989

[25] F. Solina and R. Bajcsy: "Recovery of Parametric Models from Range Images: the Case for Superquadrics with Global Deformations," *IEEE Transactions on Pattern Analysis and Machine Intelligence* Vol. PAMI-12, No. 2, pp. 131-147, 1990.

[26] J. R. Stenstrom and C. I. Connolly. Constructing object models from multiple images. *International Journal of Computer Vision*, 9(3):185–212, 1992.

[27] B. Tversky and K. Hemenway, "Objects, parts, and categories," *Journal of Experimental Psychology: General,* vol. 113, no. 2, pp. 169-193, 1984

[28] E. K. Warrington, "Agnosia: the impairment of object recognition," in *Handbook of clinical neurology,* ed. H. L. Klawans, Amsterdam: Elsevier, 1988

[29] P. Whaite and F. P. Ferrie. From uncertainty to visual exploration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 13(10):1038–1049, October 1991.

4 Curricula vitae

Franc Solina

Curriculum Vitae

Business Address:
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Home Address:
Žolgerjeva 14
61113 Ljubljana, Slovenia
Tel. +386 (61) 346 066
E-mail:
`franc@fer.uni-lj.si`

Personal: Born in Celje, Slovenia on 31 July 1955.
Single. Slovenian Citizen.
Languages: Slovenian, English, German, Croatian, and French.

Education:

1987 University of Pennsylvania, Philadelphia, Pennsylvania, USA
Ph.D. in Computer and Information Science
Advisor: Ruzena Bajcsy
Dissertation: *Shape recovery and segmentation with deformable part models*

1982 University of Ljubljana, Slovenia
M.S. in Electrical Engineering
Advisor: Ludvik Gyergyék
Thesis: *Computer Recognition of Heart Arrhythmias*

1979 University of Ljubljana, Slovenia
Dipl. Ing. degree in Electrical Engineering
Thesis: *Computer Analysis of Vector Electrocardiograms*

1974 I. Gimnazija—Bežigrad, Ljubljana, Slovenia
Secondary school baccalaureate

Positions:

Sept. 1993 – **Associate Professor** of Computer Science, University of Ljubljana
Assignment in Department of computer and information science. Teaching courses in robotic sensors, analysis of algorithms and data structures, software engineering, project management, and introductory computer science.

Jan. 1991 – **Head of the Computer Vision Laboratory**, University of Ljubljana, Department of computer and information science, Faculty of electrical engineering and computer science. Research in segmentation, shape recovery, and active vision.

1988 – 1993 **Assistant Professor** of Computer Science, University of Ljubljana
Assignment in Department of computer and information science.

November 1992	**Visiting researcher**, Department for Medical Physics, Veterinary University Vienna, Austria. Collaboration on interpretation of medical Moiré images.
Jan.–Aug. 1988	**Postdoctoral Fellow**, University of Pennsylvania Research in computer vision in General Robotics and Active Sensory Perception Laboratory. Worked on interpretation of range images of mail pieces under a US Postal Service contract. Participated and gave talks at DARPA Image Understanding/Strategic Computing review meetings (Autonomous Land Vehicle Project).
1984 – 87	**Graduate student**, CIS Department, University of Pennsylvania. Worked as teaching and research assistant. Introduced a method for recovery of compact volumetric models (superquadrics with deformations) for shape representation and segmentation. Studied quantization errors in stereo vision.
1983 – 84	**Visiting Researcher**, CIS Department, University of Pennsylvania. Work on shape representation for computer vision. Supported by the Fulbright program and the International Research and Exchange Board, New York.
1982 – 83	**Programmer**, Hydrographic Institute of the Yugoslav Navy. During one year mandatory army service assigned to the computer center of the Navy Hydrographic Institute in Split.
1979 – 82	**Research Assistant**, University of Ljubljana. Worked on computer analysis of biological signals (ECG) in the Laboratory for systems, automatics and cybernetics. Supported by a Fellowship from the Slovenian Research Council.

Awards:

The Dean's Award in 1979,
Dr. Vratislav Bedjanič award for diploma thesis, 1979,
B. Kidrič prize for innovations in 1982,
Morris and Dorothy Rubinoff award in 1988 given each year to the best Ph.D. dissertation in Computer Science at University of Pennsylvania.

Memberships:

Governing Board of Intern. Assoc. for Pattern Recognition IAPR (Slovenian Rep.),
Executive council of IEEE Slovenia Section,
American Association for Artificial Intelligence,
Institute of Electrical and Electronics Engineers,
Slovenian Society for Pattern Recognition,
Austrian Association for Pattern Recognition (ÖAGM),
Slovenian Artificial Intelligence Society,
Society for Biomedical Engineering of Slovenia.

Appointments:

Research Projects: **Principal Investigator**:
Research Project P2-1122 *Recovery of Parametric Models*, funded by the Slovenian Ministry of Research and Technology (1990–1994),

Research Project T2-0112 *Adaptive Modeling of Environment for Purposive Computer Vision*, funded by the Slovenian Ministry of Research and Technology (1994–),
Development Project X2–1022 *Info-Media*, funded by the Slovenian Ministry of Research and Technology and Multimedia, d.o.o., Ljubljana (1994–).

Invited Lectures: Columbia University, New York, 22 March 1988
Sandia National Laboratories, Albuquerque, New Mexico, 22 April 1988
41st Annual Conference of Society for Imaging Science and Technology (SPSE), Arlington, Virginia, May 1988,
Bellcore, Bell Communications Research, Morristown, New Jersey, 6 July 1988
University of Kopenhagen, September 1988
Klagenfurt, Austria, International Contact Forum, Austrian Association for Pattern Recognition, April 1991
Vienna, Austria, International Contact Forum, Austrian Association for Pattern Recognition, May 1992
Dagstuhl-Seminar on Theoretical Foundations of Computer Vision, Saarbrücken, Germany, March 1994

Vicepresident: Slovenian Pattern Recognition Society.

Reviewer: IEEE Pattern Analysis and Machine Intelligence Journal,
International Journal of Computer Vision,
CVGIP: Image Understanding,
IEEE Transactions on Image Analysis,
Electrotechnical Review,
several other International conferences in the area of computer vision.

Editor: Proceedings 6th IEEE Region 8 Mediterranean Electrotechnical Conference, Ljubljana, Slovenia, 1991 (with B. Zajc)
Proceedings of Electrotechnical and Computer Science Conference, Portorož, Slovenia, 1992, 1993
Electrotechnical Review, Ljubljana (Technical editor)

Program Committees:
Dagstuhl-Seminar on Theoretical Foundations of Computer Vision, Saarbrücken, Germany, March 1994, (co-chair),
5th International Conference on Computer Analysis of Images and Patterns CAIP'93, Budapest, Hungary
YUGRAPH'90, The Fourth Int. Conf. on Computer Graphics, Dubrovnik, 1990

Main Research Topics:

computer vision, 3-D scene interpretation, volumetric models, multi-media, visualization.

Recent Relevant Publications:

[1] Franc Solina and Ruzena Bajcsy. Recovery of mail piece shape from range images using 3-D deformable models. *International Journal of Research & Engineering, Postal Applications*, Inaugural Issue:125–131, 1989.

[2] Franc Solina and Ruzena Bajcsy. Recovery of parametric models from range images: The case for superquadrics with global deformations. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, PAMI-12(2):131–147, 1990.

[3] Ruzena Bajcsy, Franc Solina, and Alok Gupta. Segmentation versus object representation—are they separable? In Ramesh C. Jain and Anil K. Jain, editors, *Analysis and Interpretation of Range Images*, Perception Engineering. Springer, New York, 1990.

[4] Andreja Vidmar and Franc Solina. Recovery of superquadric models from occluding contours. In Reinhard Klette and Walter Kropatsch, editors, *Theoretical Foundations of Computer Vision*, Mathematical Research, Vol. 69, pages 227–240, Berlin, 1992. Akademie Verlag.

[5] Franc Solina and Aleš Leonardis. Selective scene modeling. In *Proceedings of the 11th International Conference on Pattern Recognition*, pages A:87–90, The Hague, The Netherlands, September 1992. IAPR, IEEE Computer Society Press.

[6] Jasna Maver, Aleš Leonardis, and Franc Solina. Planning the next view using the max-min principle. In D. Chetverikov and W. G. Kropatsch, editors, *Proceedings of the 5th International Conference on Computer Analysis of Images and Patterns, CAIP'93*, pages 543–547, Budapest, Hungary, September 1993. Springer-Verlag.

[7] Aleš Jaklič and Franc Solina. Separating diffuse and specular component of image irradiance by translating a camera. In D. Chetverikov and W. G. Kropatsch, editors, *Proceedings of the 5th International Conference on Computer Analysis of Images and Patterns, CAIP'93*, pages 428–435, Budapest, Hungary, September 1993. Springer-Verlag.

[8] Valentina Filova, Franc Solina, and Jadran Lenarčič. Modeling 2D image data by robust M-estimation. In *Proceedings of Mediterranean Electrotechnical Conference MELECON'94*, Antalya, Turkey, April 1994. IEEE Region 8.

[9] Franc Solina, Aleš Leonardis, and Alenka Macerl. A direct part-level segmentation of range images using volumetric models. In *Proceedings of International Conference on Robotics and Automation*, San Diego, CA, May 1994. IEEE.

[10] Aleš Leonardis, Franc Solina, and Alenka Macerl. A direct recovery of superquadric models in range images using recover-and-select paradigm. In *Proceedings of Third European Conference on Computer Vision*, Stockholm, Sweden, May 1994. Springer-Verlag.

Ruzena Bajcsy – Curriculum Vitae
Department of Computer and Information Science
School of Engineering and Applied Science
University of Pennsylvania
Philadelphia, PA 19104

Education

1957	Slovak Technical University	M.S.E.E.
1967	Slovak Technical University	Ph.D.
1972	Stanford University	Ph.D.

Position

Professor	
Primary Appointment:	Computer and Information Science Department
Secondary Appointment:	Anatomy Department, School of Medicine
Graduate Group:	Neuroscience Department, School of Medicine

Awards

- Research Fellowship, Penza, Soviet Union, October 1962–January 1963.
- Graduate Fellowship for study at Stanford University, October 1967–January 1972.
- Research Fellowship Pattern Recognition Group, CERN, Geneva, January–May 1975. (Not accepted due to immigration status at that time.)
- Visiting Scientist at INRIA-FRANCE, January–June 1979.
- Visiting Professor, Datalogisk Institute of the University of Copenhagen, April 15–June 30, 1984.
- Visiting Professor, Centro "E. Piaggio", University of Pisa, Pisa, Italy, March 1988.
- Visiting Professor, Datalogisk Institute of the University of Copenhagen, August 1988.
- Forsythe Lecturer, Department of Computer Science, Stanford University, February 1989.
- Visiting Scientist, Department of Psychology, Queen's University, Kingston, Canada, September 1989.
- AAAI Fellow, American Association for Artificial Intelligence, 1990.
- Visiting Scientist, ATR Communications System Research Laboratory, Kyoto, Japan, October 1990.
- Visiting Scientist, Electro-Technical Laboratory, Tsukuba, Japan, January 1991.
- IEEE Fellow, Institute of Electronic and Electrical Engineers, 1992.

Professional Experience

1957-1962	Research engineer, Electro-acoustic Department, Tesla, Bratislava, Czechoslovakia.
1962-1964	Maintenance engineer, (for computer URAL 2), Computation Center, Slovak Technical University, Bratislava, Czechoslovakia.

Teaching and Research Experience

1956-1957	Instructor, Department of Mathematics, Slovak Technical University, Bratislava, Czechoslovakia.
1964-1967	Assistant Professor, Department of Computer Science, Slovak Technical University, Bratislava, Czechoslovakia.
1967-1968	Research Assistant, Artificial Intelligence Project, Stanford University, Stanford, California.
1968-1969	Teaching Assistant, Department of Computer Science, Stanford University, Stanford, California.
1972-1977	Assistant Professor, Department of Computer and Information Science, University of Pennsylvania, Philadelphia.
1977-1984	Associate Professor, Department of Computer and Information Science, University of Pennsylvania, Philadelphia.
1984-	Professor, Department of Computer and Information Science, University of Pennsylvania, Philadelphia.
1985-1990	Chair, Department of Computer and Information Science, School of Engineering and Applied Science, University of Pennsylvania.

Editorial Boards

- Co-editor of special issue of *Computer Vision, Graphics, and Image Processing*, 1980.
- Associate Editor of *IEEE Trans. on Pattern Analysis and Machine Intelligence* since 1981.
- Editor of the *Newsletter of the International Association for Pattern Recognition*, 1981-1984.
- Associate Editor of the *Computer Graphics and Image Processing Journal* since 1983.
- Associate Editor of the *Pattern Recognition Letters* since 1983.
- Associate Editor of *Journal of Robotic Systems* since 1983.
- Associate Editor of *Journal of Computer Vision* since 1986.
- Area Editor of *CVGIP: Image Understanding* since 1989.

Conference Chairs

- Co-chairman of PRIP–Chicago, 1979.
- Publicity chairman of the International Pattern Recognition Conference, 1980.

- Co-Chairman, Second International Conference Computer Vision, December 5-8, Tarpon Springs, Florida, 1988.
- Vice Chairman, 10th International Conference on Pattern Recognition Conference, Atlantic City, NJ, June 16-21, 1990.
- Program Chair, International Joint Conference of Artificial Intelligence (IJCAI), Chambery, France, 1993.

Invited Speaker

- The Optical Society Meeting in Orlando, December 1981.
- Data Processing Management Association Regional Conference, Allentown, PA, "Machine Recognition of Shapes from Vision and Touch", May 13, 1983.
- The 1983 NYU Symposium on Artificial Intelligence for Business, New York University, "Integrating Vision and Touch for Robotics Applications", May 18-20, 1983.
- Seminar and Workshop on Sensors for Robotics and Flexible Automation, University of Rhode Island, Kingston, RI, "Shape From Touch", June 8-9, 1983.
- Distinguished Lecturer Series, University of Minnesota, Computer Science, "Active Perception vs Passive Perception" and "Integration of Vision and Touch for Recognition Purposes", Spring 1986.
- JPL/NASA Space Telerobotics Workshop, Pasadena, CA, "Object Apprehension Using Vision and Touch", 1987.
- AI '87 Japan Conference, "Active Perception", pp. 549-554, 1987.
- American Academy of Arts & Sciences, MIT, "Processing of Somatosensory Information in Biological and Artificial Systems", March 27-28, 1989.
- Information Technology Research Centre, Queen's University, Kingston, Ontario, "Active Perception and Exploratory Robotics: Examples of Disassembly", October 5, 1989.
- SPIE, Advances in Intelligent Robotic Systems Symposium, "Sensor Fusion II: Human and Machine Strategies", November 6-8, 1989.
- Tenth Anniversary Colloquium Series, Department of Computer Science, Brown University, "Perception via Active Exploration: Examples of Disassembly", February 13, 1990.
- University of Massachusetts, Amherst Colloquium, "Active Perception", March 1991.
- 7th Scandinavian Conference on Image Analysis, Aalborg University, Aalborg, Denmark, "Learning and Lessons Learned in Computer Vision", August 1991.
- AAAI Workshop on Artificial Intelligence, "Functionality: What is it and how can we represent it?", November 1991.
- DARPA Manufacturing Workshop, "Reverse Engineering", November 1991.
- NEC Research Institute, "Active Perception", December 1991.
- Navy Center for Applied Research in Artificial Intelligence, "Active Perception", February 1992.
- McGill University, McGill Research Center for Intelligent Machines, "3-D Object Representation and Recognition", March 1992.

- DARPA Workshop on Whole Body 3-D Electronic Imaging of the Human Body, "3-D Surface and Volume Segmentation", March 1992.
- ARO Workshop, "Science Issues in Intelligent Manufacturing," March 1992.
- Siemens/Princeton University Electrical Engineering Department, "Electronic Eye Workshop", 1992.
- Pennsylvania State University Department of Transportation Institute, 1992.
- Lehigh University Colloquium, 1993.
- University of Wisconsin Colloquium, 1993.
- General Motors Research Laboratory, 1993.
- University of Ljubljana, Slovenia, 1993.
- The First Clark Atlanta University Army Conference on Information Sciences and Technologies, "Artificial Intelligence and Challenges in Robotics and Manufacturing", February 1993.
- Carnegie Mellon University School of Computer Science, Distinguished Lecturer Series, "Cooperative Agents: Machines and Humans", March 1993.
- University of Pennsylvania, Medical Image Processing Group, "Overview of Image Understanding: GRASP Laboratory Activities", April 1993.
- Newton Institute for Mathematical Sciences, Cambridge, England, June 1993.
- University of Southern California Computer Science and Computer Engineering Distinguished Lecturer, February 1994.

Other Activities

- Organizer of workshop on the Representation of Three-Dimensional Objects, University of Pennsylvania, May 1-2, 1979. Sponsored by NSF.
- Member of the organizing committee of the Int. Medical Image Processing Conference, Berlin, October 1982.
- Research Initiation Grant Program Panel Review, National Science Foundation, March 8-9, 1983.
- Congressional Office of Technology Assessment Workshop, Committee on Appropriations, United States Senate March 18-19, 1984.
- Organizer of the Joint United States-France Second Workshop on Selected Topics in Robotics, University of Pennsylvania, Philadelphia, PA, November 7-9, 1984. Sponsored by NSF.
- Member of Program Committee, IJCAI '85, Los Angeles, CA, August 18-23, 1985.
- Engineering Equipment Awards Panel, National Science Foundation, March 26, 1986.
- Consultant, Advisory Committee, National Science Foundation, May 1, 1985 - April 4, 1986.
- Member, Panel for Manufacturing Engineering, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, 1986 - 1989.

- Member, Advisory Committee for Design, Manufacturing, and Computer-Integrated Engineering for the National Science Foundation, January 1987 - December 1989.
- Chairman, Review Committee for Undergraduate Programs in Computer Science, Loyola University, March 1988
- Chairman, Review Committee for Undergraduate Programs in Computer Science, Tulane University, March 1988.
- Program Committee Member, Topical Meeting on Image Understanding and Machine Vision, Cape Cod, MA, June 12-14, 1989.
- Member, Advisory Committee for the CISE Office of Cross-Disciplinary Activities (CDA), 1989.
- Member, National Defense Science and Engineering Graduate Fellowship Program Evaluation Panel, March 1989.
- NATO Advanced Research Workshop on Robots and Biological Systems, Il Ciocco, Tuscany, Italy, June 26-30, 1989.
- NATO Advanced Study Institute (ASI), "Scene Segmentation in the Framework of Active Perception", Maratea, Italy, July 16-19, 1989.
- NATO Closing Workshop on Sensory Systems for Robotic Control, Il Ciocco, Tuscany, Italy, October 30 - November 3, 1989.
- Program Committee Member, International Workshop on Sensorial Integration for Industrial Robots: Architectures and Applications, Zaragoza, Spain, November 22-24, 1989.
- International Evaluation Group Member, Computerized Image Processing, The Swedish National Board for Technical Development, Ministry of Industry, Stockholm, Sweden, April 1-7, 1990.
- Evaluation Panel Member, Midterm Review, Manufacturing Research Corporation of Ontario, Premier's Council Technology Fund, April 30, 1990 - May 2, 1990.
- Co-Organizer, "Encounter of Computer Vision and Mathematics", University of Pennsylvania, May 21-23, 1990. Sponsored by the ARO.
- Member, Rating Committee, Regents Doctoral Evaluation Project, The New York State Education Department, 1989 - 1990.
- Member, Science Council for Applied Mathematics and Computer Science, Universities Space Research Association, April 1990 - December, 1993.
- Member, Committee to Assess the Scope and Direction of Computer Science and Technology, Commission on Physical Sciences, Mathematics, and Applications, National Research Council, May 1990.
- Organizer of NSF/DARPA Workshop on Identification of Research Needs for a Mobile Platform with Material Handling Capabilities, University of Pennsylvania, November 1990.
- Member, National Research Council Board for Computer Science and Telecommunications, 1991.
- Invited Participant, University of Chicago, Department of Computer Science, Artificial Intelligence Laboratory, Workshop on Active Vision, August 1991.
- Invited Participant, Rutgers University, Rutgers Cognitive Science Conference, November 1991.

- Invited Participant, CESDIS Science Council Meeting, February 1992.
- Member, NSF/CISE Institutional Infrastructure Program Advisory Board, March 1992.
- Invited Participant, ARO Workshop on Science Issues in Intelligent Manufacturing, March 1992.
- Organizer of DARPA Workshop on Computational Sensors, University of Pennsylvania, May 1992.
- Member, AAAI Fellow Selection Committee, 1991 - 1992.
- Member, NIST National Research Board, 1987 - 1992.
- Member, IJCAI Inc. Board of Trustees.
- Member, University of Minnesota Computer Science Department Review Committee, May 1992.
- Chair, University of British Columbia Computer Science Department Review Committee, 1992.
- Member, NASA Computer Science Advisory Board, 1990 - 1992.
- Member, NSF Advisory Committee for Engineering, 1992.
- Invited Participant, National Research Council Workshop on Expanding Access to Japanese Robotics R&D, 1992.
- Member, NSF/CISE Directorate Advisory Committee, 1992.
- Organizer, ECUS/NSF Workshop on Vision, "Ruzenagaard," Havnebyen, Denmark, July, 1922.
- Member, University of Maryland System Blue Ribbon Committee on Research and Public Service, 1992.
- Member, Program Committee, International Conference on Computer Vision, Berlin, Germany, May 11-14, 1993.
- Member, National Science and Engineering Research Council of Canada, IRIS Standing Committee, 1993.
- Member, NIH Site Visit Committee, Washington, DC. 1993.
- Member, Computing Research Board of Directors, 1993.

Recent Relevant Publications

1. "Recovery of Mail Piece Shape from Range Images Using 3-D Deformable Models", *International Journal of Postal Research and Engineering*, 1989 (co-author: F. Solina).
2. "Part Description and Segmentation of Range Image by Integration of Contour, Surface, and Volumetric Primitives", *Topical Meeting on Image Understanding and Machine Vision*, Technical Digest Series, Vol. 14, 100-103, (Optical Society of America, Washington, D.C.) 1989.
3. "Recovery of parametric models from range images: the case for superquadrics with global deformations", *IEEE Transactions on PAMI*, Vol. 12, No. 2, February 1990 (co-author: F. Solina).
4. "Occlusions as a Guide for Planning the Next View", *IEEE Trans. on PAMI,* Vol. 15, No. 5, May 1993 (co-author: J. Maver).

5. “Image Segmentation with Detection of Highlights and Inter-reflections Using Color”, *International Journal of Computer Vision,* in press, 1994 (co-authors: A. Leonardis and S.W. Lee).

6. “Segmentation versus object representation – are they separable?” in *Analysis and Interpretation of Range Images*, eds. Ramesh Jain and Anil Jain, Springer-Verlag, 1989 (co-authors: F. Solina and A. Gupta).

7. “Color Image Segmentation with Detection of Highlights and Local Illumination Induced by Inter-reflections”, *Physics-Based Vision, Principles and Practice,* Ed. G.E. Healey, S.A. Shafer and L.B. Wolff, Jones and Bartlett Publishers, Boston, 1992 (co-authors: S.W. Lee and A. Leonardis).

8. “Range Image Interpretation of Mail Pieces with Superquadrics”, *Proceedings AAAI 1987,* Seattle, WA, July, 1987, pp. 733-737 (co-author: F. Solina).

9. “Rapid Prototyping from Physical Models,” *Proceedings of the Darpa Workshop on Information Technology for Manufacturing Automation and Concurrent Engineering,* Palo Alto, CA, June 16-18, 1992, pp. 721-724 (co-authors: V. Koivunen, V. Kumar and J-M. Vezien).

10. “Geometric Methods for Building CAD models from Range Data”, *9th International Conference on CAD/CAM, Robotics and Factories of the Future,* Newark, NJ, 1993 (co-author: V. Koivunen).

Aleš Leonardis

Curriculum Vitae

Business Address:
University of Ljubljana
Faculty of Electrical Engineering and Computer Science
Tržaška 25, 61001 Ljubljana, Slovenia
Tel. +386 (61) 123 11 21
Fax. +386 (61) 264 990

Home Address:
Pleteršnikova 26
61113 Ljubljana, Slovenia
Tel. +386 (61) 325 980

Ales.Leonardis@fer.uni-lj.si

Personal: Born in Ljubljana, Slovenia on 17 April 1961
Slovenian Citizen.
Single.
Languages: Slovenian, English, and French.

Education:

1993 University of Ljubljana, Ljubljana, Slovenia
Ph.D. in Computer and Information Science
Advisors: R. Bajcsy, University of Pennsylvania, Philadelphia, USA, and F. Solina
Dissertation: *Image Analysis Using Parametric Models: Model-Recovery and Model-Selection Paradigm*

1988 University of Ljubljana, Ljubljana, Slovenia
M.S. in Electrical Engineering
Advisors: N. Pavešić and L. Gyergyek
Thesis: *Using Hierarchical Shape Representation to Recognize and Locate Two-Dimensional Patterns*

1985 University of Ljubljana, Ljubljana, Slovenia
Diploma Engineer degree in Electrical Engineering
Advisor: N. Pavešić
Thesis: *A System for Automatic Inspection of Printed Circuit Boards*

1980 I. Gimnazija—Bežigrad, Ljubljana, Slovenia
Secondary school baccalaureate

Positions:

Oct. 1992 – **Assistant**, University of Ljubljana, Department of computer and information science, Faculty of electrical engineering and computer science.
Courses: Principles of computer science, Programming I, Algorithms and data structures I, Robotic sensors, Software engineering, and Project management with computers.

June 91 – May 93 **Graduate Student**, University of Ljubljana
Department of computer and information science. Worked in the Laboratory for computer vision. Research in segmentation and shape recovery in computer vision. Supported by the Ministry for Science and Technology of the Republic of Slovenia.

Sep. 88 – May 91 **Research Assistant**, University of Pennsylvania, U.S.A.
Research in computer vision in General Robotics and Active Sensory Perception Laboratory. Worked on color image segmentation and on interpretation of range images. Introduced a method for recovery of surface and curve models for shape representation and segmentation. Participated and gave talks at DARPA Image Understanding Workshop, ARO seminars, and several international conferences, among them ICPR'90 (Atlantic City, U.S.A.) and ICCV'90 (Osaka, Japan).

Oct. 85 – Aug. 88 **Graduate student**, University of Ljubljana
Department of electrical engineering. Worked as a research assistant in the Laboratory for systems, automatics, and cybernetics. Research in computer vision (multilevel shape representations, motion detection, visual inspection, recognition). Supported by a Fellowship from The Research Council of Slovenia.

Jan. 1986 **Teaching Assistant**, Elected to be a teaching assistant in the Area of systems, automation, and cybernetics, University of Ljubljana.

July – Sep. 1985 **Research Assistant**, ISKRA-Delta (DEC), Computer company, Ljubljana. Worked on integration of a CAD system for designing printed circuit boards and a system for automatic visual inspection of printed circuit boards.

Awards: Student award for academic achievements in 1982,
The Dean's award in 1985,
Dr. Vratislav Bedjanič award for diploma thesis in 1985,
1st Prize at the 5-th Annual Meeting of Young Researchers, Ljubljana, 1992 (with J. Maver and A. Jaklič),
OÄGM Prize 1992, Graz, Austria, 1993.

Memberships: Institute of Electrical and Electronics Engineers,
Slovenian Association for Pattern Recognition.

Appointments:

Research projects: Worked on the Research Project P2-1122 *Recovery of Parametric Models* funded by the Slovenian Ministry of Research and Technology,
Research Project T2-0112 *Adaptive Modeling of Environment for Purposive Computer Vision* funded by the Slovenian Ministry of Research and Technology (1994-),
Development Project X2-1022 *Info-Media*, funded by the Slovenian Ministry of Research and Technology and Multimix, d.o.o., Ljubljana (1994-).
Also worked on research projects supported by The Research Council of Slovenia, UEK-002/85, RSS-03-2671/86, RSS-03-2671/87, RS-03-2671/88.

Invited Lectures:

NTT, Japan, December 1991,
ETH Zentrum, Inst. für Kommunikationst., Zürich, Switzerland, June 1993,
Dagstuhl-Seminar on Theoretical Foundations of Computer Vision, Saarbrücken, Germany, March 1994.

Reviewer: IEEE Pattern Analysis and Machine Intelligence Journal,
International Journal of Computer Vision,

CVGIP: Image Understanding,
IEEE Transactions on Neural Networks,
Informatica, and
several other International conferences in the area of computer vision.

Editor: GraspNews, Vol. 7, No. 1, 1991 (with S.W. Lee and P. Sinha)

Main Research Topics:
computer vision, 3-D scene interpretation, purposive and qualitative vision, learning.

Recent Relevant Publications:

[1] R. Bajcsy, S. W. Lee, and A. Leonardis. Color image segmentation with detection of highlights and local illumination induced by inter-reflections. In *Proceedings of the 10th International Conference on Pattern Recognition*, pages 785–790, Atlantic City, NJ, June 1990.

[2] A. Leonardis, A. Gupta, and R. Bajcsy. Segmentation as the search for the best description of the image in terms of primitives. In *Third International Conference on Computer Vision*, pages 121–125, Osaka, Japan, December 1990. IEEE.

[3] A. Leonardis and R. Bajcsy. Finding parametric curves in an image. In G. Sandini, editor, *Proceedings of The Second European Conference on Computer Vision—ECCV-92*, pages 653–657. Springer-Verlag, 1992. Lecture Notes in Computer Science, LNCS-Series Vol. 588.

[4] F. Solina and A. Leonardis. Selective scene modeling. In *Proceedings of the 11th International Conference on Pattern Recognition*, pages A:87–90, The Hague, The Netherlands, September 1992. IAPR, IEEE Computer Society Press.

[5] F. Pernuš, A. Leonardis, and S. Kovačič. Non-information-preserving shape features at multiple resolutions. In *Proceedings of the 11th International Conference on Pattern Recognition*, pages B:166–169, The Hague, The Netherlands, September 1992. IAPR, IEEE Computer Society Press.

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Appendix III.

U.S. - SLOVENE JOINT FUND - PROJECT PROPOSAL BUDGET

Principal Investigators's Name: Franc Solina JF No.: ______

Short Project Identification Title: Recovery of Parametric Shape Models in Images Date: 25 March 1994

		YEAR ONE		YEAR TWO		YEAR THREE		3 YEARS TOTAL	
		SIT	USD	SIT	USD	SIT	USD	SIT	USD
A. Travel / Slovene	1. Domestic Slovene								
	2. International Airfare	263.600		263.600		263.600		790.800	
	3. Per Diem + Lodging		8.000		8.000		8.000		24.000
Travel / U.S.:	4. International Airfare		1.000		1.000		1.000		3.000
	5. Per Diem + Lodging	369.040		527.200		527.200		1.423.440	
TRAVEL COSTS TOTAL (A):		632.640	9.000	790.800	9.000	790.800	9.000	2.214.240	27.000
B. Equipment:	1. Instruments	355.860						355.860	
	2. Spare Parts	65.900	1.000	197.700	1.000	197.700	1.000	461.300	3.000
	3. Materials & Supplies	131.800		197.700		197.700		527.200	
EQUIPMENT COSTS TOTAL (B)		553.560	1.000	395.400	1.000	395.400	1.000	1.344.360	3.000
C. Other Direct	1. Consultants								
	2. Computer Services								
	3. Publication Costs								
	4. Other (Describe)	131.800		131.800		131.800		395.400	
OTHER DIRECT COSTS TOTAL (C):		131.800		131.800		131.800		395.400	
D. Institutional Indirect Costs:									
INDIRECT COSTS TOTAL (D):									
E. GRAND TOTAL PROJECT COSTS (A + B + C + D):		1.318.000	10.000	1.318.000	10.000	1.318.000	10.000	3.954.000	30.000

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March 28, 1994

Professor Franc Solina
Faculty of Electrical Engineering and Computer Science
University of Ljubljana
Trzaska cesta 25
61001 Ljubljana
Slovenia

Dear Franc:

I am delighted by the prospect of our mutual cooperation. The problem of shape representation and range image processing is very dear to my heart, as you know. It is not only one of the most important scientific problems in Computer Vision, but also it has tremendous importance for applications, notably in manufacturing.

I am immensely impressed by your recent results in integrating contour, surface and volumetric representation towards a general purpose shape recognizer of man-made objects. I am hoping to use it in our work in the near future.

We have recently engaged in an ARPA funded project on reverse engineering in which we take a range image of a mechanical part, and then search for the most compact representation of these measurements, given a prescribed accuracy. As you know, there is a tradeoff between the complexity of fit and the data compression ratio. Dr. Visa Koivunen, who works on this project, has developed an adaptive fitting algorithm that can adjust to the prescribed accuracy. This project is directly related to the proposed project, in that different shape representations are required depending upon the manufacturing process. Another similar aspect of this work is how to seemlessly combine different views of the part.

I am looking forward to our mutually beneficial collaboration very much.

Sincerely,

Ruzena Bajcsy

Ruzena Bajcsy
Professor and Director
GRASP Laboratory